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ANTENNA CHARACTERISTICS OF HETERODYNE RECEIVERS OF CO_2 LASER EMITTERS

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16. Abstract

An experimental setup for measurement of antenna characteristics of a heterodyne receiver of CO_2 laser emitters and its operation are described and illustrated. A 6.6 W LG-17 CO_2 laser, with a 0.005 rad divergence, was the radiation source, the Doppler frequency shift device provided a frequency shift of 20 MHz, and Ge-Au and Ge-Zn-Sb photoresistors, with 2 × 2 mm detection area, at a temperature of 78°K, was used. A 20 dB gain and a 15-fold narrowing of the directivity pattern, to 0.007 rad, were achieved. Comparison of the experimental curves presented shows that generalized reciprocity theorem can be used to estimate the directivity of a heterodyne detector. It is stated that use of a nonlinear element can eliminate the possibility of failure to detect a weak signal due to atmospheric turbulence.

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ANTENNA CHARACTERISTICS OF HETERODYNE RECEIVERS OF CO_2 LASER EMITTERS

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The directivity of a heterodyne receiver of CO_2 laser /40*
emitters was investigated directly, and by means of the generalized theorem of reciprocity. It was found that, with a heterodyne detector for a receiver, with a sensitive area of 2×2 mm^2, the directivity pattern is narrowed to 0.007 rad.

Coherent detection was carried out earlier in the visible and IR ranges [1, 2]. There is particular interest in heterodyne detection of CO_2 laser radiation, which is explained by the high power of CO_2 lasers, as well as by the 8-14 μ transparency window in the atmosphere. Heterodyne detection sharply attenuates the effect of various noise sources, including the effect of black body radiation, existing at the 10.6 μ wavelength, at a temperature of 300°K. An increase in ν selectivity is accompanied by an increase in k selectivity, since heterodyning is subject only to those types of signal fluctuations, which are excited in the body of the detector by heterodyne radiation, to which attention was first drawn, in connection with the problem of sensitivity, in [3].

Analysis [4] has shown that, by matching the heterodyne field and the signal in the plane of an optical detector, the intermediate frequency signal is proportional to the ratio $[\sin(\pi d\alpha/\lambda)]/(\pi d\alpha/\lambda)$, where α is the slope angle of the signal front relative to the heterodyne front, d is the diameter of the /41
signal beam cross section and λ is the light wavelength. From the point of view of antenna theory, this is equivalent to the

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* Numbers in the margin indicate pagination in the foreign text.

assertion [5] that an optical heterodyne detector is characterized by an effective area S_n, connected with the solid detection angle Ω, by a limitation of the type $S_n \Omega_n \simeq \lambda^2$. In this case, the optical elements located in the paths of the signal and heterodyne beams (or in the path of one of them) can change the ratio of S_n and Ω_n, but cannot change the value of their product.

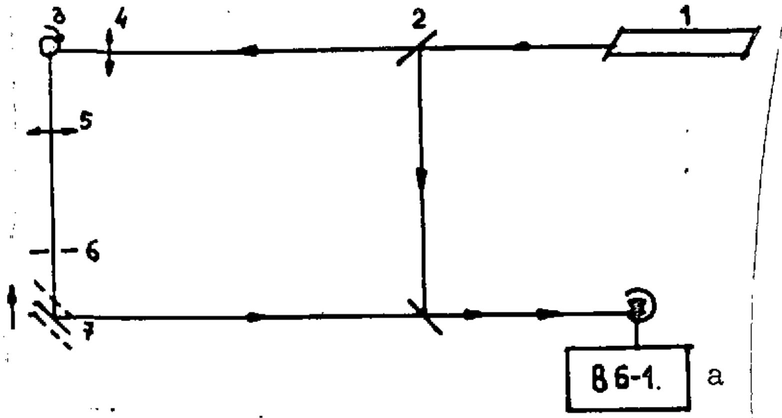

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Fig. 1.
Key: a. V6-1

In our experiment, measurement of the antenna characteristics was carried out according to the following scheme (Fig. 1): radiation from the CO_2 laser (1), passing through beam-splitting mirror (2) (the branched power was used as the heterodyne signal), was focused on a device, creating a Doppler shift of the signal frequency (3). The signal fell on scanning mirror (7) through converging lens (5) and diaphragm (6). The signal reflected from the scanning mirror was added to the heterodyne signal in second beam-splitting mirror (8), after which both signals fell on the photosensitive surface of photoresistor (9). Displacement of the scanning mirror changed the angle of incidence of the /42
signal beam and made it possible to measure the detector directivity pattern. The frequency difference signal was recorded.

A standard CO_2 laser (LG-17), with a 6.6 W output power and 0.005 rad divergence, was used in the experiments. The laser operated in the TEM_{01q} mode. The beam splitter was made of BaF_2.

The signal frequency Doppler shift device was a six-pointed star, 20 mm on a side, fastened to the axle of a DID-2 motor. At a rotation frequency of 330 Hz, the frequency shift amounted to 20 MHz.

Investigation of the antenna characteristics of the heterodyne detector were carried out with Ge-Au and Ge-Zn-Sb photoresistors. Both photoresistors have a 2 × 2 mm detection area, and they were cooled to a temperature of 78°K.

The scanning mirror was set to within ±0.05 mm.

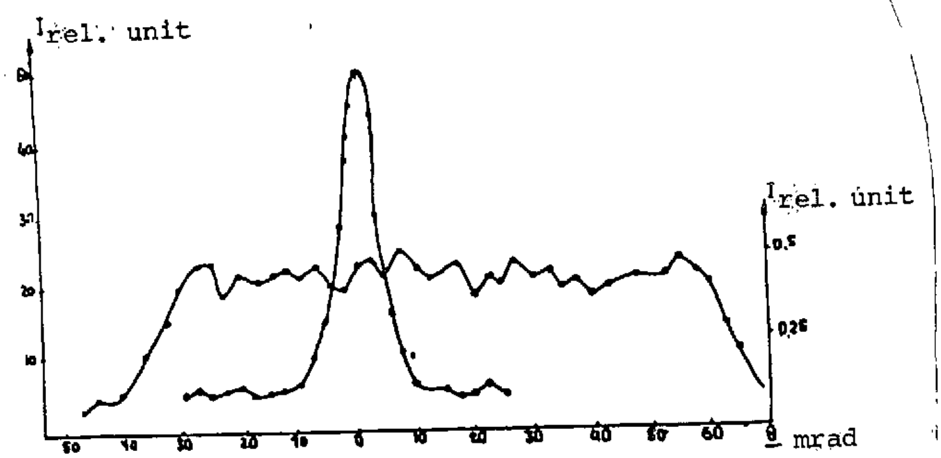

Fig. 2.

The results of measurements of the directivity characteristics of the heterodyne detector of the CO_2 laser emitter are presented in Fig. 2. The nature of the curve obtained coincides quite well with that calculated theoretically. According to the estimate of the detection area size, for which coherent detection conditions were satisfied in our experiment, is 0.15 × 0.15 mm.

To compare the directivity patterns of the direct and heterodyne detection, it is sufficient to overlap the heterodyne beam The results of the comparison are presented in Fig. 2.

The gain of the output signal, using heterodyne detection, is 20 dB, and the directivity pattern is narrowed 15-fold, to 0.007 rad.

In determination of the detector directivity, the super-high frequency reciprocity theorem can be used, which, applied to our case, is formulated in the following manner: "if a photo-detector is replaced by a mirror having the same configuration as the detection area of the photodetector and, if the reflected heterodyne beam passes through all those elements, through which the incident signal beam must pass in the forward direction, the /44 distribution of the heterodyne field obtained in a distant zone gives the heterodyne detector directivity pattern."

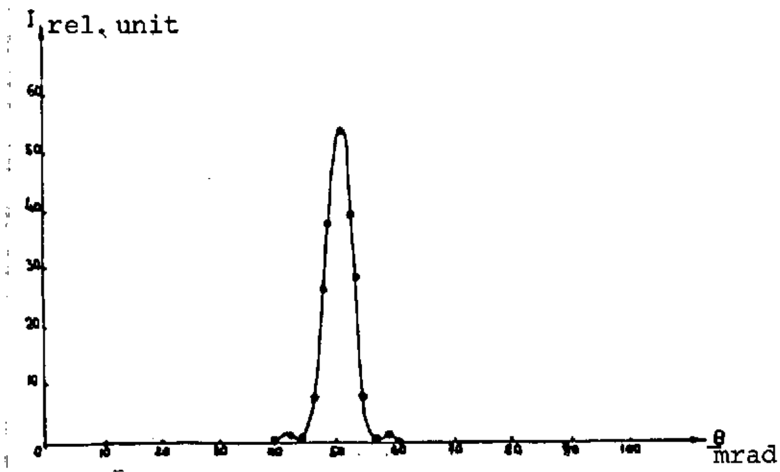

Fig. 3

Using a gold-plated metallic mirror, 2 × 2 mm in size, we obtained the directivity pattern represented in Fig. 3. Visualization and measurement of the heterodyne field distribution was accomplished by the thermographic method.

A comparison of the curves of Figs. 2 and 3 shows that the generalized reciprocity theorem can be used to estimate the directivity of a heterodyne detector.

Atmospheric turbulence may cause fluctuations in the arrival angle of the signal. In this case, the heterodyne detection directivity may prevent detection of a weak signal. Use of a point diode or isotropically radiating heterodyne as a nonlinear element eliminates this effect.

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